

Ammonium and phosphate removal using batch laboratory cultures by microalgae and cyanobacteria isolated from Costa Rica water bodies

Manuel Campos-Rudin^{1,2} & Ana Margarita Silva-Benavides^{*1,2}

1. Escuela de Biología, Universidad de Costa Rica, San Pedro, San José 2060, Costa Rica; manuel.campos@ucr.ac.cr, ana.silva@ucr.ac.cr
2. Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Ciudad de la Investigación, Universidad de Costa Rica, San Pedro, San José 2060, Costa Rica.

* Correspondence

Received 10-I-2017. Corrected 24-V-2017. Accepted 03-I-2018.

Abstract: This research analyzed three green microalgae (*Scenedesmus* sp., *Chlamydomonas* sp., and *Chlorella* sp.) and two cyanobacteria (*Synechocystis* sp. as unicellular strain and *Nostoc* sp. as filamentous strain) native from Costa Rica to remove high concentrations of ammonium and phosphate. Cultures were exposed for 120 h to initial concentrations of 70 mgL⁻¹ ammonium and 9 mgL⁻¹ phosphate, under constant light intensity of 60 μmol m⁻²s⁻¹. *Chlorella* sp. showed the highest growth rate, followed by *Chlamydomonas* sp. and the cyanobacteria *Nostoc* sp. In contrast, *Scenedesmus* sp. and *Synechocystis* sp. cultures grew less than the other ones. The highest percentage of ammonium removal was achieved with *Chlorella* sp. followed by *Chlamydomonas* sp. and *Synechocystis* sp., then *Scenedesmus* sp. and *Nostoc* sp. Microalgae removed totally the initial phosphate concentration within 72 h, while cyanobacteria *Synechocystis* sp. and *Nostoc* sp. removed phosphate partially. These microorganisms are promising for wastewater reclamation. Rev. Biol. Trop. 66(Suppl. 1): S83-S91. Epub 2018 April 01.

Key words: microalgae, cyanobacteria, ammonium, phosphorus, growth, productivity, wastewater.

The use of green microalgae in tertiary wastewater treatment was first proposed in the 1980s (Oswald, 1989). This technology is still rather limited, mainly because of the space it requires on land and the need for warm climatic conditions. Microalgae wastewater treatment systems are influenced by two major factors: 1) an adequate mixing of the culture suspension to ensure sufficient light to the cells, and 2) harvesting the microscopic cells from the treated water efficiently in order to complete the process (Benemann, Kooman, Weissman, & Eisenberg, 1980; Benemann, 1989; Oswald, 1989; Acién, Gómez-Serrano, Morales-Amaral, Fernández-Sevilla, & Molina-Grima, 2016). Several studies have been dedicated to the use of the microalgae for tertiary wastewater treatments, including species of *Chlorella* sp. (Tam & Wong, 1996; de-Bashan & Bashan, 2004;

Aslan & Karapinar, 2006) and *Scenedesmus* sp. (González, Cañizares, & Baena, 1997; Voltolina, Cordero, Nieves, & Soto, 1999; Martínez, Sánchez, Jiménez, Yousfi, & Muñoz, 2000; Voltolina, Gomez-Villa, & Correa, 2005). Cyanobacteria, free or immobilized in a matrix, have also been investigated (De la Noüe, Lessard, & Proulx, 1993; Chevalier, Proulx, Lessard, Vincent, & de la Noüe, 2000; Olgúin, Galicia, Mercado, & Pérez, 2003). Other potential use of the green microalgae, it is related with the biomass generated by bioremediation procedures, which can be coupled to biotechnological applications like biogas, biofuel or biofertilizers production (Ansari, Hussain, Nawar, Qayyum, & Ali, 2017; Diniz, Silva, Araújo, & Chaloub, 2017).

Microalgae and cyanobacteria require nitrogen (N) and phosphorus (P) to synthesize

nucleotides, amino acids, lipids, and carbohydrates (Dyhrman, 2016). These molecules are needed in energy transfer during metabolic reactions. *N* can be found in compounds like ammonium (NH_4^+) or nitrate (NO_3^-) and *P* can be found in phosphates (PO_4^{3-}) (Glass, Wolfe-Simon, & Anbar, 2009). Microorganisms and plants regularly used NO_3^- , NH_4^+ and PO_4^{3-} in soils, fresh and oceanic water for many processes. However, high concentrations of *N* and *P* can promote water eutrophication which represents a serious ecological problem. Nutrient enrichment has generated blooms of some species of microorganisms like bacteria, cyanobacteria and microalgae, which release toxic compounds that impact ecosystems and biodiversity. High concentrations of NH_4^+ and PO_4^{3-} in water bodies can be generated by human activities, like domestic waste waters, the intensive use of fertilizers and agro industrial activities (Cai, Park, & Yebo, 2013). In Costa Rica, the main sources of water contamination are organic compounds, fertilizers and industrial sources which produce a high input of NH_4^+ and PO_4^{3-} in rivers and marine waters (Hidalgo, 2012).

In this work, we present data on the removal capacity of NH_4 -N and PO_4^{3-} -P, the growth rates and productivity of three microalgae (*Chlorella* sp., *Scenedesmus* sp. and *Chlamydomonas* sp.) and two types of cyanobacteria, the unicellular type as *Synechocystis* sp. and the filamentous type as *Nostoc* sp. isolated from Costa Rican water bodies.

MATERIALS AND METHODS

Organisms and culture conditions:

The organisms studied were native strains of microalgae (*Scenedesmus* sp., *Chlorella* sp. and *Chlamydomonas* sp.) and cyanobacteria (*Nostoc* sp. and *Synechocystis* sp.) isolated from different waters bodies of Costa Rica. *Scenedesmus* sp., *Chlorella* sp. and *Synechocystis* sp. were isolated from a small polluted creek in Río Azul, San José. *Chlamydomonas* sp. was found in a secondary treatment oxidation

pond operated by the Instituto Costarricense de Acueductos y Alcantarillados in Liberia, Guanacaste. The cyanobacteria *Nostoc* sp. was isolated from a lagoon in Monteverde, Puntarenas. Cells were maintained in laboratory conditions in BG₁₁ medium (Rippka, 1988) in glass columns with a 400 ml nutritive medium, at 28 °C, bubbled with a mixture of air/CO₂ (97:3, v/v) and illuminated with cool white fluorescent light at 60 $\mu\text{mol photons m}^{-2}\text{s}^{-1}$ measured on the surfaces of the cultures.

The culture medium was a synthetic medium (SM), enriched with NH_4Cl and K_2HPO_4 to adjust the concentration of NH_4 -N and PO_4^{3-} -P to the same level found in Río Azul. The average initial concentrations of NH_4 -N and PO_4^{3-} -P in the starting cultures were 70 mgL^{-1} and 9 mgL^{-1} , respectively. The pH of the medium was adjusted to 7.0 before sterilization.

Experimental design: For the experimental set up, cells in the log phase were harvested by means of centrifugation (Beckman Coulter, model Avanti J-26 XP Centrifuge, Brea, CA, USA) and re-suspended in filtered sterile distillate water (three times) to eliminate any traces of BG₁₁ nutrients.

The experiments were carried out in duplicate 350 mL culture samples in 500 mL Erlenmeyer flasks. The initial dry weight was 200 mgL^{-1} . Cultures were incubated at a temperature ranging from 24-26 °C in an orbital incubator (New Brunswick Scientific, USA), under 60 $\mu\text{mol photons m}^{-2}\text{s}^{-1}$ measured on the surface of the cultures with a flat quantum sensor Hansatech model SKP 200. All experiments were carried out under continuous illumination, with constant shaking of 75 RPM and supply of air/CO₂ ratio 97/3, v/v. The starting pH of the cultures was 7.0; it was controlled daily and adjusted to the initial value by adding a diluted solution of HCl. The constant supply of CO₂ and the daily adjustment of the pH to 7 avoid the PO_4^{3-} precipitation and NH_4 -N degassing as ammonia (NH_3) at high pH. Controls (three replicates) without algal cells were maintained under the same conditions.

Collected data: From each treatment, 10 mL of culture were sampled at 24 h intervals to measure $\text{NH}_4\text{-N}$ and $\text{PO}_4^{3-}\text{-P}$ concentrations and culture dry weight. The controls were evaluated daily to detect any loss of $\text{NH}_4\text{-N}$ by outgassing or $\text{PO}_4^{3-}\text{-P}$ by precipitation. Cell dry weight determination was carried out on triplicate 5 mL samples. Each sample was filtered through a 0.45 μm pore size pre-weighted glass fiber filters (Whatman, Maidstone, UK) and then dried at 100 °C for two hours. $\text{PO}_4^{3-}\text{-P}$ and $\text{NH}_4\text{-N}$ concentrations (mgL^{-1}) were determined by using a Photometer (Hanna Instruments: Multiparameter Bench Photometer for Laboratories model HI3200), in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, 1992). Samples were centrifuged at 6.000 xg for five minutes to separate the algal cells, and care was used to avoid any loss of gaseous ammonia during experiments.

The mean productivity of each batch run, Q_x ($\text{mg L}^{-1}\text{day}^{-1}$), was calculated as: $(X_1 - X_0) / t_1 - t_0$ where X_1 (mgL^{-1}) is the dry weight measured at the time t_1 (day), and X_0 mgL^{-1} is the dry weight at time t_0 (day).

The total amount of $\text{NH}_4\text{-N}$ removal during the experiment, Q_N (mgL^{-1}), was calculated as:

$$Q_N = N_o - N_m,$$

where N_o (mgL^{-1}) is the initial $\text{NH}_4\text{-N}$ concentration and N_m (mgL^{-1}) is the $\text{NH}_4\text{-N}$ concentration remaining in the medium at the end of the experiment.

The total amount of $\text{PO}_4^{3-}\text{-P}$ removal during the experiment (mgL^{-1}) was calculated as: $Q_p = P_o - P_m$, where P_o (mgL^{-1}) is the initial $\text{PO}_4^{3-}\text{-P}$ concentration and P_m (mgL^{-1}) is the $\text{PO}_4^{3-}\text{-P}$ concentration remaining in the medium at the end of the experiment.

Statistical analysis: The variables were examined using an analysis of variance (ANOVA) with a significance level of $p < 0.05$. All the analyses were done in IBM SPSS statistics program v. 21.

Growth rate and culture productivity:

Calculation of growth rate over time indicated that no lag phase took place, with the first phase being exponential growth (μ) within 24 h, where all the studied strains showed a maximum growth rate (μ) (Fig. 1). Thereafter, growth rate remained constant followed by a decline at 72 h, except for *Chlorella* sp. which dropped drastically after 24 h. This strain showed higher growth rate compared to the other cultures ($\mu = 0.0296\text{h}^{-1}$), while the cyanobacterium *Synechocystis* sp. had the lowest growth rate ($\mu = 0.0039\text{h}^{-1}$). Significant differences in growth rates occurred between microalgae and cyanobacteria ($p < 0.05$) (Fig. 1). Among the microalgae, *Chlorella* sp. showed the highest average productivity ($178.16 \text{ mg L}^{-1}\text{d}^{-1}$) and among cyanobacteria, *Nostoc* sp. productivity was higher ($85.8\text{mg L}^{-1}\text{d}^{-1}$) compared to that attained with *Synechocystis* sp. ($34.56 \text{ mg L}^{-1}\text{d}^{-1}$) (Fig. 2).

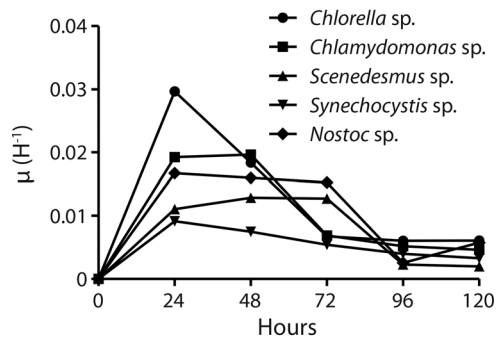


Fig. 1. Specific growth rate versus time (h) recorded in cultures of microalgae and cyanobacteria grown artificial medium.

Nitrogen Removal: Nitrogen removal varied among the strains ($p < 0.001$) (Fig. 3a), except between the microalgae *Scenedesmus* sp. and the cyanobacteria *Nostoc* sp. where removal was similar ($p > 0.05$) (Table 1). After 24 h of culture, a decrease in its concentration was observed in all the strains (between 5 % and 25 % of the initial $\text{NH}_4\text{-N}$ concentration). *Chlorella* sp. strain reduced the initial $\text{NH}_4\text{-N}$

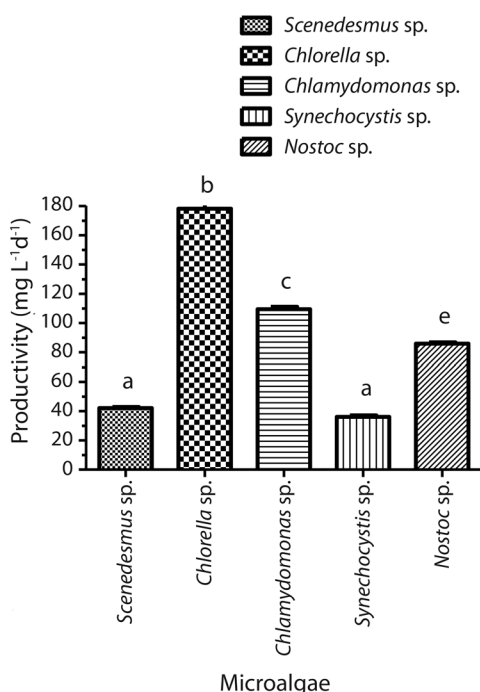


Fig. 2. Mean productivity ($\text{mg L}^{-1}\text{d}^{-1}$) of microalgae and cyanobacteria cultures. The values in the same column followed by different letters are significantly different ($p < 0.05$). (*) a-a *Synechocystis* sp. and *Scenedesmus* sp. are not significantly different ($p > 0.05$).

more than the half of the initial concentration within 48 h achieving almost a total removal of $\text{NH}_4\text{-N}$ at 120 h (92.25 %). Among the other microalgae, *Chlamydomonas* sp. performed better than *Scenedesmus* sp. (37.5 % and 27 %) respectively, while *Synechocystis* sp. showed a little higher removal of $\text{NH}_4\text{-N}$ compared to *Nostoc* sp. (Table 1).

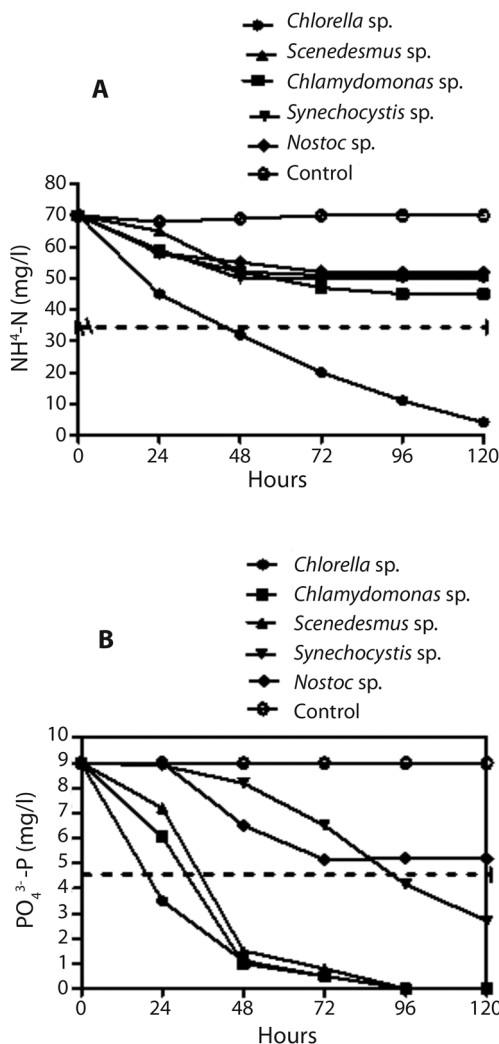


Fig. 3. $\text{NH}_4\text{-N}$ (a) and $\text{PO}_4\text{-3-P}$ (b) removal kinetics attained by the microalgae and cyanobacteria. Data were fitted with a one-phase exponential decay curve. Broken line indicates a 50 % reduction in the initial ammonium and phosphate concentration.

TABLE 1
Total removal (%) of $\text{NH}_4\text{-N}$ and $\text{PO}_4\text{-3-P}$ after 120 h by microalgae and cyanobacteria

	$\text{NH}_4\text{-N}$ removal (%)	$\text{PO}_4\text{-3-P}$ removal (%)
<i>Chlorella</i> sp.	92.25 *	100 n.s.
<i>Chlamydomonas</i> sp.	37.50 *	100 n.s.
<i>Scenedesmus</i> sp.	27.00 n.s.	100 n.s.
<i>Synechocystis</i> sp.	29.75 *	70.00 *
<i>Nostoc</i> sp.	24.25 n.s.	48.55 *

(n.s.) no significant differences. (*) Significantly different ($p < 0.001$).

Phosphorus removal: Microalgae removed 100 % of the $\text{PO}_4^{3-}\text{-P}$ at the end of 120 h ($p > 0.05$), while cyanobacteria had the lowest percentages of removal ($p < 0.001$) (Table 1). The kinetics of $\text{PO}_4^{3-}\text{-P}$ removal was faster in all microalgae strains. There was a reduction of more than 50 % after 24 h in *Chlorella* sp. and after 36 h in *Scenedesmus* sp. and *Chlamydomonas* sp., with complete $\text{PO}_4^{3-}\text{-P}$ removal within 96 h (Fig. 3b). The cyanobacteria *Synechocystis* sp. showed a 50 % reduction within 96 h but did not completely remove $\text{PO}_4^{3-}\text{-P}$ (70 %) at the end of the experiment, *Nostoc* sp. showed the lowest $\text{PO}_4^{3-}\text{-P}$ removal (48.55 %) (Fig. 3b).

DISCUSSION

Ideal candidate algal species for wastewater treatment should present the main following characteristics: 1) able to growth with high concentrations of inorganic nutrients, 2) efficiency to remove the pollutants, 3) high metabolic activity in order to cope with harsh environmental conditions, and 4) high growth rate. Microalgae strains tested in this work, showed better growth than the cyanobacteria one. An initial phase of log growth after 24 h in all the strains followed by a decreased of the biomass accompanied by a pronounced fall in the $\text{PO}_4^{3-}\text{-P}$ concentration, indicated that the growth was strongly affected by the presence of $\text{PO}_4^{3-}\text{-P}$ and $\text{NH}_4\text{-N}$ in the medium, especially $\text{PO}_4^{3-}\text{-P}$, suggesting that the consumption of this ion more than $\text{NH}_4\text{-N}$ by algae.

Culture growth depends on different factors such as light intensity, pH, nutrients, carbon dioxide, mixing, and temperature. In wastewater, growth depends in part by the active nutrient uptake of the photosynthetic cells and their transformation into biomass (Voltolina et al., 2005). An excessive cell density could limit the light penetration into the water column and thus reduce the growth, particularly in scarcely mixed cultures.

The mixing of the culture is one of the most important requirements to obtain high productivities of the microalgal biomass (Abalde, Cid,

Fidalgo, Torres, & Herrero, 1995); it allows to maintain a homogeneous distribution of nutrients to the cells, prevents sedimentation and allows a more uniform light distribution in the water column. In our experiments, the constant mixing of the cultures favored the productivity of *Chlorella* sp. and *Chlamydomonas* sp. strains. Kong, Li, Martínez, & Ruan (2010) and Martínez et al., (2000) reported the agitation of the culture as one important factor in the growing of *Chlamydomonas reinhardtii* and *Scenedesmus obliquus*.

However, shaking in cyanobacteria cultures may have had a negative effect on the growth for example of *Nostoc* sp. This cyanobacterium has gas vacuoles for floating, favoring a better light incidence on the cell surface in absence of mixing. Shaking of the cultures, may represent an obstacle to buoyancy of *Nostoc*, reducing the possibility for it to capture the light and forsaking growth of cells. Similar findings have been reported by Silva-Benavides & Torzillo (2012) in cultures of monoalgal *Planktothrix*. Visser, Ibelings, Van Der Veer, Koedood, & Mur (1996), reported reduction in the growth of filamentous cyanobacteria as *Aphanizomenon* sp., in a lake in mixing conditions. Low pH in the water favored the growth of green algae and diatoms more than cyanobacteria (Shapiro, 1990; Visser et al., 1996). In our case, the pH of the cultures was close to 7.0, a condition that could have promoted the growth of algae more than cyanobacteria, which can to be more abundant in alkaline mediums.

Algal growth was accompanied by a decrease in $\text{NH}_4\text{-N}$ and $\text{PO}_4^{3-}\text{-P}$ concentrations in all the cultures, indicating that *N* and *P* removal could be mainly due to algal uptake and assimilation. The maintenance of pH 7 during the experiments prevents the conversion of ammonium to ammonia gas which it happens at high pH and phosphate precipitation which it occurs at low pH (Nurdogan & Oswald, 1995; Silva-Benavides & Torzillo, 2012).

The uptake and assimilation rates of ammonium are higher than NO_3 by primary producers because is less energetic demanding (Von Ruckert & Giani, 2004; Escudero,

Blanco, Lacalle, & Pinto, 2014), and many genes involved in nitrate/nitrite assimilation are repressed in the presence of ammonium (Fernández, Llamas, & Galván, 2008). The incorporation of ammonium into algal cells occurs through the action of the enzyme glutamine dehydrogenase and by transports of the AMT/MEP enzyme family (Raven & Giordano, 2016), which has been demonstrated in *Chlamydomonas* sp. (Fernández, Llamas & Galván, 2008; de Montaigu, Sanz- Luque, Macias, Galvan, & Fernández, 2011).

The microalga *Chlorella* sp. showed a bioremoval capacity of almost 93 % of the ammonium, which was considerably higher than what is reported in the literature (Tam & Wong, 1996; Aslan & Karapinar, 2006; Silva-Benavides & Torzillo, 2012). The highest growth rate of this alga suggests that cells can recycle *N* in proteins into the cells to maintain their growth. Aslan & Karapinar (2006), pointed out that *Chlorella vulgaris* is able to remove around 50 % of $\text{NH}_4\text{-N}$ when the concentration is between 41.8-92.8 mgL^{-1} and the removing efficiency decreased at concentrations over 129 mgL^{-1} .

Similar trends have been reported in *Chlamydomonas* in high concentrations of $\text{NH}_4\text{-N}$, as the case of *Chlamydomonas acidophila*, which removed between 51.0 and 68.0 mgL^{-1} of $\text{NH}_4\text{-N}$ with an initial concentration of 95 and 650 mgL^{-1} in 240 h (Escudero et al., 2014). In our case, this alga showed a 37 % removal of $\text{NH}_4\text{-N}$.

The microalgae *Scenedesmus* sp. can remove up to 100 % ammonium when the concentration of this ion is below 40 mgL^{-1} (González, Cañizares, & Baena, 1997; Martínez et al., 2000; Voltolina et al., 2005), but concentrations higher than 100 mgL^{-1} affect their removal capacity (Azov & Goldman, 1982; Godos et al., 2010; Park, Jin, LIm, Park, & Lee, 2010). In our study, the $\text{NH}_4\text{-N}$ concentration was 70 mgL^{-1} , which it could have affected the removal of this ion by this alga. The microalga *Scenedesmus* sp. can use both sources of nitrogen (NO_3 and NH_4^+) without any preference (Park et al., 2010).

González-Garcinuño, Tabernero, Sánchez-Alvarez, del Valle, & Galán (2014) showed that the best growing medium in autotrophic conditions for *Scenedesmus abundans* was based on NH_4NO_3 , where the ammonium bioremoval increased if the solution has nitrate. This fact could explain the reduced removal of ammonium by this alga in our study, which the only source of *N* was from NH_4Cl .

Aslan & Karapinar (2006), report that *Chlorella* sp. removes $\text{PO}_4^{-3}\text{-P}$ efficiently when its concentration is lower than 7.7 mgL^{-1} , which was similar in our experiment. Given the microalgae cultures exhausted the content in the medium within 48-96 h, we argued that $\text{PO}_4^{-3}\text{-P}$ limited the growth of cultures, principally for *Chlorella* sp. The growth stops drastically at 24 h of the experiment; it is supposed that the decreasing of $\text{PO}_4^{-3}\text{-P}$ from 24 h could severely reduce the growth rate of this microalga, contrary to *Scenedesmus* sp. and *Chlamydomonas* sp. which showed a linear growth during the time of $\text{PO}_4^{-3}\text{-P}$ reduction in the medium. The fast removal pattern of $\text{PO}_4^{-3}\text{-P}$ against $\text{NH}_4\text{-N}$ for all the three microalgae has also been reported by Lynch et al. (2015), who found 3.3 times faster phosphate removal against ammonium in *Chlorella* sp. and *Scenedesmus* sp. Our study demonstrated that *Chlorella* sp. and *Chlamydomonas* sp., the uptake of $\text{NH}_4\text{-N}$ and $\text{PO}_4^{-3}\text{-P}$ have contributed to the higher growth and productivity of these microalgae.

The cyanobacteria show less tolerance to high concentrations of NH_4^+ than microalgae (Glass et al., 2009; Collos & Harrison, 2014). In cyanobacteria, ammonium is incorporated into carbon skeletons mainly through the glutamine synthetase-glutamate synthase cycle (Herrero, Muro-Pastor, & Flores, 2001) and glutamate synthase (Muro-Pastor, Reyes, & Florencio, 2005). In our study, both cyanobacteria did not show a good performance in the removal *either P or N*. The majority of the enzymes used by cyanobacteria in *N* assimilation required several metals as cofactors (Glass et al., 2009). The synthetic medium used in this study was not supplemented with metals, so it could reduce the capacity to uptake ammonium.

Nostoc sp. is more sensitive to ammonium applications than others cyanobacterias in agricultural fields which induce a decrease of pH in the medium (Dai, Deblois, Liu, Jeneau & Qui., 2008). We avoided this negative effect by keeping a neutral pH. In reports with different sources of residual waste water, *Nostoc muscurum* showed a removal rate of 40 - 60 % for $\text{PO}_4^{-3}\text{-P}$ and 20.9 -96 % for $\text{NH}_4\text{-N}$ (El-Sheekh, El-Shouny, Osman, & El-Gammal, 2014), similar to our findings. Concerning the assimilation of ammonium by phytoplankton species, cyanobacteria are better competitors than eukaryotic algae (Von Ruckert & Giani, 2004). We would expect a higher removal capacity by *Synechocystis* sp. and *Nostoc* sp. against microalgae; however, we did not find this trend, suggesting that conditions other than $\text{NH}_4\text{-N}$ concentration could be influenced its uptake.

Nostoc sp., removed the lowest $\text{NH}_4\text{-N}$ or $\text{PO}_4^{-3}\text{-P}$ compared with all the strains studied, behaving like a low nutrient removal filamentous strain. This fact has been already observed by Seale, Boraas, & Warren (1987) and Subramanian, Sumathi, & Sivasubramanian (2009). These authors found that the uptake of PO_4^{-3} by *Nostoc* sp. was very low when sodium was not included in the medium solutions as in the present study.

The differences of removal of $\text{PO}_4^{-3}\text{-P}$ and $\text{NH}_4\text{-N}$ and the growth of the different microalga and cyanobacteria used in this experiment, suggest that the variations depend on the metabolic condition of the algae, the strain of algae and environmental conditions in the medium. The microalgae *Chlorella* sp. it is an excellent choice to pursue bioremediation of eutrophic waters with high input of *N* and *P*. In terms of removal of $\text{PO}_4^{-3}\text{-P}$, all the algae, except *Nostoc* sp. showed an excellent performance compared to other studies (Aslan & Karapinar, 2006). There are some possible strategies to improve bioremediation and growing performance, the use of different sources of *N* in the medium (González-Garcinuño et al., 2014; Lynch et al., 2015) or co-cultures microalgae and cyanobacteria (Silva-Benavides & Torzillo, 2012).

The use of these native cyanobacteria strains as filamentous *Nostoc* sp. and the unicellular *Synechocystis* sp., together with the green microalgae *Chlorella* sp., *Scenedesmus* sp. and *Chlamydomonas* sp., which are better acclimated to the specific environmental conditions of the country are good candidates to removed N and P compounds derived from urban o agricultural wastewater. The resulting biomass obtained from the bioremediation process, it can be used for different biotechnological applications, like biofertilizers or biofuels production, and these uses of the biomass can also give an economical input decrease the cost of waste water treatment procedures.

ACKNOWLEDGMENTS

This work was performed funds provided by the “Vicerrectoría de Investigación de la Universidad de Costa Rica”, project number 808-B3-136. We thank Jenaro Acuña for his advice in chemical aspects. Jose Moncada gives the statistical support. Jimena Samper and Mario Espinoza for the review of the document. We also want recognize laboratory work of Dayana Vega, Diana Acuña, Andres Lee and Alejandra Solano.

RESUMEN

Remoción de amonio y fosfato en cultivos de laboratorio con microalgas y cianobacterias aisladas de cuerpos de agua de Costa Rica. La presente investigación utilizó las microalgas *Scenedesmus* sp., *Chlamydomonas* sp. y *Chlorella* sp. y las cianobacterias *Synechocystis* sp. y *Nostoc* sp. nativas de Costa Rica, con el propósito de analizar la capacidad de remoción de amonio y fosfato. Las cepas se colocaron en medio de cultivo sintético, con concentraciones iniciales de amonio de 70 mgL^{-1} y fosfato de 9 mgL^{-1} . El cultivo se realizó durante 120 h, con luz constante a una intensidad de $60 \mu\text{mol m}^{-2}\text{s}^{-1}$. Se cuantificaron las siguientes variables cada 24 h en todos los cultivos: a) la tasa de crecimiento (μ), b) productividad ($\text{mgL}^{-1}\text{h}^{-1}$), c) concentración de amonio y fosfato. La microalga *Chlorella* sp. presentó la mayor tasa de crecimiento, luego *Chlamydomonas* sp. y la cianobacteria *Nostoc* sp. Los cultivos *Scenedesmus* sp. y *Synechocystis* sp. presentaron un menor crecimiento. La mayor remoción de nitrógeno se presentó en *Chlorella* sp., seguida por *Chlamydomonas* sp. y *Synechocystis* sp., *Scenedesmus* sp. y *Nostoc* sp. El fosfato se

removió en forma total por las microalgas antes de las 72 h, mientras que en *Synechocystis* sp. y *Nostoc* sp. fue removido parcialmente. El estudio indica potenciales aplicaciones especialmente de la microalga *Chlorella* sp. en la remoción de amonio y fosfato en aguas residuales urbanas.

Palabras clave: microalga, cianobacteria, nitrógeno, fósforo, crecimiento, productividad, agua residual.

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